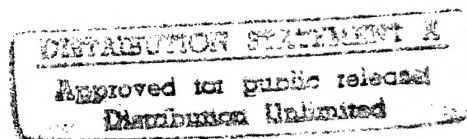

Study of Alternative Methods for the Management of Liquid Scintillation Counting Wastes

L. Roché-Farmer

Office of
Nuclear Material Safety and Safeguards

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**Division of Fuel Cycle and Material Safety
Office of Nuclear Material Safety and Safeguards
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Washington, D.C. 20555**



TABLE OF CONTENTS

	<u>PAGE</u>
Foreword	III
I. Background	1
A. Liquid Scintillation Counting	1
B. Problems Associated with Liquid Scintillation Counting Waste (LSCW)	3
C. Disposal Methods Available Provided Under 10 CFR 20	4
1. General (Section 20.301, 10 CFR Part 20)	4
2. Releases of Air and Liquid Effluents (Section 20.106, 10 CFR Part 20)	4
3. Sewer Disposals (Section 20.303, 10 CFR Part 20)	5
4. Burials (Section 20.304, 10 CFR Part 20)	5
5. Incineration (Section 20.305, 10 CFR Part 20)	6
7. Other Methods (Section 20.302, 10 CFR Part 20)	6
II. Purpose of the Report	7
III. Waste Management Alternatives for LSCW	7
A. Evaporation	7
B. Distillation	9
C. Solidification	12
1. Microencapsulation	12
2. Polymerization	13
D. Conversion to a Less Hazardous Chemical Form	15
E. Combustion	17
1. Incineration	17
2. Addition to Fuel	19
IV. Summary	20

V. References	23
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List of Tables

I. Relative Scintillation Yields of Some Commonly Used Solvents	25
II. Toxicity of Toluene, Xylenes and 1,2,4-trimethylbenzene	26
III. Physical Properties of Solvents Used in Most Common LSC Cocktails	29
IV. Toxicity of Benzoic Acid and Phthalic Acid	31
V. Research Octane Ratings of Hydrocarbons	32

APPENDICES

Appendix 1. Guideline for Incineration of Liquid Scintillation Waste	33
Appendix 2. Radiation Dose Assessment	35

FOREWORD

The Nuclear Engineering Waste Disposal Site in Richland, Washington, is the only radioactive waste disposal facility that will accept liquid scintillation counting wastes (LSCW) for disposal. That site is scheduled to discontinue receiving LSCW by the end of 1982. We do not anticipate that any other waste burial facilities will accept radioactive organic liquids in the future. It should be also noted that waste collectors will probably not be able to accept your LSCW in the future since they in turn will have no method for its disposal. Alternative methods for management of LSCW must be found.

This document explores alternatives presently available for management of LSCW. Some of the alternatives outlined require further development before they can be made operational. You are encouraged to assess your alternatives and begin to develop a method for management of your LSCW other than sending it to the Richland burial ground. You will note that one of the most viable alternatives for LSCW management appears to be incineration. Information relevant to obtaining a license amendment to incinerate this material is included with the paper.

STUDY OF ALTERNATIVE METHODS FOR THE MANAGEMENT OF LIQUID
SCINTILLATION COUNTING WASTES

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I. Background

A. Liquid Scintillation Counting

Liquid Scintillation Counting (LSC) is used in biomedical research and mostly owes its popularity to the ability of measuring tritium easily; it also facilitates ^{14}C assay. In the past ^{14}C was counted as a solid or gas with many problems associated with its quantitative analysis. There are other radionuclides assayed by this technique, e.g., ^{125}I , ^{32}P , ^{35}S , but these are not used as widely as ^3H and ^{14}C .

The scientific breakthroughs achieved with LSC have been a powerful stimulus to the increased use of the technique by the scientific community.

The objective of all procedures to prepare samples for LSC is to use a method that yields clear homogeneous preparations. The liquid scintillation preparation has three components, the solvent, the solute and the sample itself. The "solvent" and "solute" constitute what is known as the LSC cocktail. The samples may be non-aqueous, e.g., steroids, lipids, and non-polar organics. However, aqueous samples are by far the most common type encountered in the research laboratory. These aqueous samples are incorporated into emulsifiable

LSC cocktails. Although an emulsified sample is not truly homogeneous, it behaves as such in the counting environment.

Scintillation counting involves the following basic processes: (a) nuclear radiation produces a number of excited molecules in the cocktail organic solution, (b) these excited molecules will either emit photons or efficiently transfer the energy to an acceptor (fluor) which in turn will emit the photons. The release of energy in the form of photons is referred to as fluorescence, which can be measured by a photomultiplier tube and converted to electrical pulses. The solvent dissolves the sample and scintillator (fluor) and acts as a medium for absorbing the energy of the nuclear radiation. A good solvent for LSC must be a compound with molecules that produce excited states easily, i.e., aromatic-type molecules (toluene, p-xylene, 1,2,4-trimethylbenzene), dioxane and others. The solute acts as a source of photons after accepting energy from the excited solvent molecules. Efficient energy transfer is accomplished by a homogeneous or emulsified sample preparation. There is also a variation among the aromatic solvents in scintillation efficiency (see Table 1). This efficiency is improved by using high-grade (purity) solvents. The availability of toluene in high purity at moderate prices has led, in the past, to its use over p-xylene and 1,2,4-trimethylbenzene even though these latter solvents have higher scintillation efficiencies. At one time, dioxane, owing to its complete miscibility with water, was the preferred solvent for aqueous samples, but it has some objectionable features. First, it is a powerful carcinogen, thus it presents potential health hazards to laboratory personnel. Secondly, dioxane is unstable, decomposing spontaneously to form products, such as peroxides, which act as energy quenchers. These objectionable

features of dioxane led to the development of the emulsifiable cocktails using water immiscible solvents, i.e., toluene, xylene and 1,2,4-trimethylbenzene currently used. Dioxane is used in very limited amounts, but apparently is not completely off the market.^{3,7,11}

B. Problems Associated with Liquid Scintillation Counting Waste (LSCW)

Research laboratories throughout the country are using approximately 84×10^6 LSC vials/year. This generates an average of 840,000 liters/year of LSCW. Radioactivity content is estimated at 8 Ci/year of primarily ^3H and ^{14}C which are low energy beta emitters. Although this amount of radioactivity is relatively small, LSC must be treated as radioactive waste under existing regulations. Disposal problems are compounded and some options limited because of the chemical nature of the organic solvents, e.g., their flammability and chemical toxicity (see Table II). Fires have occurred during transportation of these wastes and, at the burial sites, the organic solvents have spilled out of the 55-gallon drums in which they were buried. The spillage is probably due to the packaging procedures. The drums are normally lined with polyethylene bags. Generally, vermiculite has been used as an "absorbent" for packing the LSCW vials in the lined-drums. However, vermiculite does not absorb the LSCW. It also settles down at the bottom of the drum leaving the LSCW as free-standing liquid. The screw caps of the LSC vials (and some of the vials) are also made of polyethylene which is permeable to toluene and other LSC solvents. Even high-density polyethylene is not adequate for the long-term storage of these organic solvents. Although the LSCW does not pose a radioactive hazard itself, the organic solvents can compromise the integrity of the burial ground. The solvents may act as a vehicle for transport of other radioactive wastes through

the geologic structure. Furthermore, the solvents spilled in the burial trenches are also a fire (perhaps explosion) hazard.

Approximately 84 percent of the country's low-level radioactive waste was being buried at Barnwell, South Carolina. But since June 21, 1979, radioactive organic liquids were banned from this site. Two other facilities were available in Beatty, Nevada and Richland, Washington. The future use of these sites for burial of radioactive organic liquids is very questionable.

C. Disposal Methods Available Provided Under 10 CFR 20

Considering only the radioactivity aspect, the methods presently available to licensees are:

1. General (Section 20.301, 10 CFR Part 20)

- a. By transfer of wastes to authorized recipients as authorized by 10 CFR Parts 30, 40, or 70 (e.g., commercial waste disposal ground).
- b. As authorized by Section 20.106, 20.302, or 20.304, 10 CFR Part 20 (see 2, 3, and 4 in the following).

2. Releases of Air and Liquid Effluents (Section 20.106, 10 CFR Part 20)

- a. Air and liquids may be released to unrestricted areas provided the concentration of licensed material in the air or liquids do not exceed the concentrations specified in Appendix B, Table II, 10 CFR Part 20, when averaged over a period not exceeding one year, e.g., for ^3H , 2×10^{-7} $\mu\text{Ci/ml}$.

- b. Higher limits may be approved provided the licensee provides information described in 20.106(b). Approvals are granted on an individual basis (approvals require amendments to licenses).

3. Sewer Disposals (Section 20.303, 10 CFR Part 20)

- a. Must not exceed daily concentration limits specified in Appendix 13, Table I, Column 2 of 10 CFR Part 20,
or
- b. Quantities must not exceed 10 times the amounts shown in Appendix C of 10 CFR Part 20,
and
- c. The average concentration of releases in any one month must not exceed the limits specified in Appendix 13, Table I, Column 2 of 10 CFR Part 20,
and
- d. The gross quantity of licensed material must not exceed 1 Curie per year.

4. Burials (Section 20.304, 10 CFR Part 20)*

- a. Total quantity buried at any one location and time must not exceed 1000 times the amounts specified in Appendix C of 10 CFR Part 20.
- b. Burials must be at a minimum depth of four feet.
- c. Burials must be separated by at least six feet and no more than 12 burials may be made per year.

*This rule is expected to be deleted in the near future. It will be substituted by a rule which requires specific approval by license amendment for burial.

5. Incineration (Section 20.305, 10 CFR Part 20)

The incineration of liquid scintillation wastes may, in some instances, be a viable means for disposal of such wastes. As required by Section 20.305, 10 CFR Part 20, specific approval must be obtained for such incineration.

The attached guideline, INCINERATION OF LIQUID SCINTILLATION WASTE, specifies the type of information which should be included in an application for authorization to incinerate liquid scintillation waste. (See Appendix 1)

6. Other Methods (Section 20.302, 10 CFR Part 20)

Includes other methods not covered specifically in 10 CFR Part 20 (e.g., by license amendment authorizing licensee to dispose of krypton 85 gas by release to atmosphere although the concentrations exceed limits in 10 CFR Part 20). Commercial radioactive waste disposal requirements are covered by this Section in 10 CFR Part 20.

In regard to the 10 CFR 20 provisions, it should be noted that:

- a. The sewer and burial disposals of the LSC organic solvents are generally not permissible because of state and local restrictions on disposal of organic solvents.
- b. The Sewer Disposal, 10 CFR- 20.303 says: "No licensees shall discharge material into a sanitary sewerage system unless: (a) It is readily soluble or dispersible in water." The most widely used solvents in the LSC cocktails, i.e., toluene, xylene and 1,2,4-trimethylbenzene, are not soluble or dispersible in water. Dioxane is soluble in water but it is a carcinogen and must be disposed of according to the regulations for such materials.
- c. The Burial Disposal, 10 CFR-20.304, is not desirable without treatment or immobilization of LSCW because the organic solvents are a fire hazard

and may compromise the integrity of the burial ground by acting as vehicle for transport of other potentially hazardous materials.

II. Purpose of the Report: To evaluate alternative methods for the management of LSCW.

The techniques that have been evaluated as alternative methods for the management of LSCW are:

- A. Evaporation
- B. Distillation
- C. Solidification
 - 1. Microencapsulation
 - 2. Polymerization
- D. Conversion to a less hazardous chemical form
- E. Combustion
 - 1. Incineration
 - 2. Addition to fuel

III. Waste Management Alternatives for LSCW

A. Evaporation

The volatility of the aromatic solvents used in the LSC cocktails makes the use of evaporation techniques relatively easy although the process is slow. It can be made faster by blowing air on the liquid surface, large surface area containers and warm temperatures, but overall it does not demand particularly special equipment nor expenditure of energy.

The simplicity of this technique is portrayed by the following examples. Information obtained in a visit² to Todd Research and Technical Division, Galveston, Texas, indicates that some laboratories in Texas put the LSCW in shallow pans that are placed on top of ventilation hoods and allowed to evaporate. Blotting-paper at the bottom of the pan catches any particulate which might remain after the liquid evaporates, and finally discarded as regular trash. However, when extensive usage of the LSC technique generated larger volumes, the wastes were sent to Todd Research and Technical Division for disposal. Initially, Todd Research also evaporated the wastes when they were handling a volume of 1500 gallons per month, but the process has become inadequate for the 20,000 gallons/month which are being handled now from multiple sources. (They used to dispose of, among others, the LSCW generated at NIH, but have not done so since November 1978.) The waste is shipped to Todd Research in 55-gallon drums which are stored in an open field for about six months before processing. During this storage most radioisotopes used in LSC have decayed with the exception of ^3H and ^{14}C . The drums are manually opened and the vials thrown into a crusher where the vials and liquid are separated. The solid wastes (crushed vials) are surveyed for radioactivity. (Todd did not specify how these surveys were conducted.) The contaminated vials are sent to the low-level burial sites and the other vials (presumably non-contaminated) are released in the regular trash. The liquid waste goes into tanks where it evaporates by the hot Texas climate, at a faster rate in the summer than in the winter. Once the liquid is in the tank, the evaporation is accelerated by blowing air across the surface. After four or five years of this operation the sludge at the bottom of the tanks registered 10^{-4} $\mu\text{Ci/cc}$ (the volume of the sludge was not specified). Todd is planning to

incinerate the LSCW in the near future. They expect to install an incinerator, the design of which is being planned, and have it ready for operation by January 1980.

Critique of the Evaporation Technique

1. It is a very slow process.
2. It releases the radioactive material and the chemically toxic solvents into the environment.
3. It poses fire hazards.
4. If not performed at the site where the waste is generated, the potential accidents incurred during transportation must be added to the above comments.
5. It is simple and inexpensive, aside from transportation costs.

B. Distillation

Several distillation processes have been reviewed. These processes (3,4,5) involved standard distillation procedures, e.g., simple distillations, reduced-pressure distillation and fractional distillation. The major objectives given for using this technique are: (1) to reduce the volume of LSCW, and (2) recovery of distillates for potential reuse, e.g., toluene.

Overall, two major types of distillation may be considered: (1) simple distillation, and (2) fractional distillation. Each type may be performed either under atmospheric or at reduced pressures.

Simple distillation is generally used to separate any two components of a mixture which boil at least 80° apart. For materials whose boiling points differ by

30° to 80°, separation may still be effected by repeated simple distillations, but fractional distillation is a much more convenient technique for efficient separation of such mixtures or for mixtures of liquids which boil a few degrees apart. (See Table III for physical properties of solvents used in most common LSC cocktails.)

However, as mentioned in the background section, LSC preparations are mostly emulsions. Emulsions are not directly separable into their components by distillation techniques. Even fractional distillation techniques will fail since there will be formation of azeotropes.³ An azeotrope is a constant-boiling mixture (at a specific pressure) in which the pure component is never obtained. In general, the practical methods for separation of azeotropes are: chromatography, extraction, or some chemical transformation of the components followed by distillation. There are several successful techniques used in the laboratory to break down emulsions, e.g., salting out, addition of a strong acid (H_2SO_4), and addition of a solvent which would increase the density difference between the components of the emulsion. If the liquid organic layer in the emulsion is slightly lighter than the aqueous layer, as in the LSC cocktails, addition of a low density organic solvent will separate the layers. However, addition of organic solvents will only compound the LSCW problems. The salting out effect is the addition of ionic salts to the emulsion and will also lead to phase separation.

The processes which were reviewed basically used the phase separation methods described above. But one of these processes demands special equipment capable of freezing the samples to separate the aqueous and organic phases.⁴

Although distillation is routinely used in industry, it does not seem practical nor economically feasible for the small-scale LSC user.⁵ It is not as slow as evaporation, but it is generally a slow and tedious process. It is also hazardous because even though no open flame is involved (heating mantles, heat lamp, steam bath, oil bath, etc., are used for heating), the temperature must be raised and we are dealing with flammable materials. The process must be monitored at all times by well trained personnel. Thus, in distillation many potential problems can arise particularly when one deals with multicomponent systems, which is the case with LSCW.

Critique of the Distillation Technique

1. It requires trained personnel to monitor all fractions of the process.
2. It is time consuming, particularly for multicomponent systems.
3. Large industries use the process successfully on a routine basis, but it might not be practical nor economically feasible for the smaller laboratory.
4. Residue fractions must be disposed of, e.g., by incineration or by burial, according to regulations.

The following comments pertain to the recovery of "reusable material":

5. It is doubtful that to "recycle" the cocktail for further usage will be reliable because: (a) each batch will have different residual radioactivity. This will introduce appreciable source of error in future counting unless the left-over radioactivity is accurately determined, which is time consuming; (b) the "recycled" formulation will not be as the original. Thus it may require trial and error mixing ratios with the samples to obtain a homogeneous

preparation if this is ever possible. The surfactants and other compounds, which are used in the cocktails to solubilize the aqueous samples, will be depleted in the process, leaving compounds which are not able to solubilize the samples.

6. Considering the potential volume reduction of LSCW generated at the source, it might be advantageous to recover toluene, xylene, etc., for technical grade solvent use at the source.⁵ It might be particularly worthwhile to recover these solvents if they become unavailable or highly priced.¹⁰ However, for the process to be successful and economically feasible, it should be done by the appropriate industrial organization or large-scale LSC user.

C. Solidification

The fire hazards of the LSC cocktails could be diminished by solidification of wastes because this would reduce the vapor pressure of the aromatic solvents and consequently their flammability. The alternatives considered for the final disposal of the solidified waste are incineration and internment at a low-level burial site. The solidification methods that have been evaluated are:

(a) microencapsulation and (b) polymerization.

1. Microencapsulation

Microencapsulation is the entrapment of the LSCW in a polymer matrix. The microencapsulation methods that have been evaluated so far do not offer absolute assurance of solidifying the waste⁶ without liquid residues. Thus, the methods must be further developed to ensure total solidification of the waste.

The microencapsulation technique does not render a thermodynamically stable state. The organic solvents will eventually be released and evaporated from the solid matrix. For any microencapsulation technique to be useful, it should give a product that maintains its integrity for a sufficient period of time after solidification to permit transportation and final disposal. Provided that the product integrity is maintained for an adequate time, microencapsulation would be a safer waste form for transportation because the vapor pressure of the solvent is reduced. Under the assumption that the waste interred at a burial site will remain there permanently, the organic solvents will be released into the trenches over a relatively short period of time. Microencapsulation is not an adequate method to treat the LSCW if this release into the burial grounds is undesirable (see Background Section).

Critique for the Microencapsulation/Incineration/Burial Alternatives

1. The technique must be developed further.
2. The integrity of the product must be tested for the period of time elapsed from solidification until incineration.
3. It is a safer form for transportation than the methods presently used.
4. If final disposal is long term burial, it is not adequate because the organic solvents will be released.

2. Polymerization

Polymerization is "the chemical union of many small molecules to make very large molecules." The basic molecules that constitute a polymer are called monomers. Polymers, i.e., plastics, synthetic rubber, etc., are widely used in our modern world in multiple forms. But the process of polymerization is

not simple. It is achieved through the action of light, heat, pressure, or a chemical catalyst. It requires skilled personnel and special equipment.

Polymerization of the organic solvents of LSCW (after separation from the aqueous phase) has been considered as an alternative solidification method. The process is being considered by some manufacturers of labelled compounds, e.g., New England Nuclear.⁷ To date, no polymerization procedure has been proposed or used specifically for the LSCW.

However, polymerization is a true solidification of the organic solvents since it involves direct chemical bonding of the compounds of concern, unlike the previously discussed microencapsulation techniques. As for the encapsulation method, the final disposal for the polymerized-waste under consideration are incineration, and interment at a low-level burial site. There is no need for polymerization if the final disposal is incineration at the site where the waste is generated. Assuming that: (1) a successful polymerization process for the LSCW can be developed, and (2) the polymerized-waste form is transported to an incinerator or burial ground, the following comments must be considered.

Critique for the Polymerization/Incineration/Burial Alternatives

1. The polymerized-waste form would be safer for transport than the methods presently used.
2. It is stable; there will not be release of the volatile compounds.

3. The polymerization process requires specialized personnel, technology and equipment.
4. It is rather expensive.

Additionally, for the burial alternative:

5. Burial of the waste implies long-term interment at a shallow site. Materials are not inert forever with respect to their surroundings. With time, water and air, e.g., from rain, will react with the waste, breaking down the polymeric macromolecules into smaller fractions. As long as the polymer maintains its integrity it is not likely that any migration will occur. However, the smaller fractions will migrate. Compared with the microencapsulation, the polymerized-waste will maintain its integrity for longer period of time. Accelerated tests on the integrity of possible polymeric-waste forms should be performed to determine their impact on the environment.

D. Conversion to a Less Hazardous Chemical Form

The problems associated with the aromatic solvents used in LSC cocktails are their flammability and chemical toxicity (see Table II). It is possible to lessen the hazards associated with them by conversion of the organic phase solvents to other chemical forms which might be disposed of more easily. The first step involved is the separation of the organic and aqueous phases. This may be accomplished by the salting-out technique. The aqueous phase might be disposed of by release as a liquid effluent or release to the sewer under 10 CFR 20 provisions. The cocktails use different solvents which can be identified by the manufacturers. Some of the solvents, e.g., toluene, may be oxidized, under mild conditions, to give benzoic acid. The properties of

benzoic acid are given in Table IV. Comparison of these properties of benzoic acid with those for toluene in Table II, shows the decrease in potential hazards for the latter compound. This alternative should be explored and tested in the laboratory.

The technique offers potential application for LSC cocktails using toluene and xylene. The xylene may be oxidized to phthalic acid (see Table IV). For dioxane and 1,2,4-trimethylbenzene some method other than oxidation should be used for conversion to less hazardous chemical forms. The 1,2,4-trimethylbenzene would not likely oxidize under mild conditions. Unlike all the above aromatic solvents, dioxane is an ether and soluble in water. As all ethers, it absorbs oxygen from the air to form unstable peroxides which on heating may be an explosive hazard. Thus, oxidation is not recommended for dioxane based cocktails.

Critique of Conversion to a Less Hazardous Chemical Form

1. It may be done on site, where waste is generated.
2. It may be simpler and less costly than present methods of processing waste for disposal.
3. It offers potential application for LSC cocktails using toluene and xylene.
4. It may be applicable for use by small research laboratories.
5. Disposal of aqueous phase under 10 CFR 20 provisions and of the less hazardous chemical form of the organic phase to a suitable burial site.

E. Combustion

Combustion of the LSCW is a promising alternative since it would ideally convert noxious materials to CO_2 and H_2O . The combustion process may be carried out without utilizing the energy content of the waste, i.e., as in incineration, or it may utilize the LSCW energy content, e.g., by addition to heating fuel. But before these alternatives are discussed, it is necessary to consider the relative environmental impacts of burning radioactive materials. The radionuclides used in LSC are all short-lived except H^3 and C^{14} . As stated earlier, the radioactivity contained in LSCW is estimated to be eight Ci per year, primarily from tritium and carbon-14. The ratio of tritium to carbon-14 is estimated to be about 100 to 1. Appendix 2 contains calculated doses for the maximally exposed individual downwind from incineration of LSCW. The maximum doses are from the ingestion pathway and are 0.5 mrem per year per Ci of tritium burned in a single incinerator and 3.1 mrem per year per 10 millicuries of carbon-14.

1. Incineration

As was mentioned previously in this report, Todd Research is considering the installation of an incinerator to burn the LSCW, but it is only in the planning stage.

The Mound Facility in Miamisburg, Ohio, has a cyclone incinerator, which has been used to dispose of their solid operational waste, e.g., disposable laboratory gowns, towels, shoe covers, etc.⁸ The incinerator has been in operation for a total of 432 hours over a 2-1/2 year span, and 4 hours of maximum operation at a time. The waste is placed in stainless steel or carbon steel drums, which last 70-100 and 10 incineration cycles, respectively. To our knowledge, the Mound Facility is the only laboratory which has actually tested the incineration technique for LSCW. This waste, i.e., the LSC vials with their contents, are fed to the incinerator at a controlled rate. A drum full of waste cannot be incinerated because there is enough vapor pressure build-up in the process to make it dangerous.⁸

The Cyclone Incinerators, built by a company in Massachusetts, range in cost from \$148,000 to \$500,000, depending on the degree of automation of the equipment. Besides this equipment cost, a special building and support equipment for the incinerator would be needed.

Total combustion of the LSCW is apparently an effective method to break down the solvent molecules into, ideally innocuous species, i.e., CO_2 or H_2O . But off-gas analyses to determine effluents have not been carried out.⁸ The vials are either glass or polyethylene. Aside from the problems that molten glass might cause, the polyethylene should, with total combustion, burn to CO_2 and H_2O . Thus, incineration seems a promising alternative to dispose of the LSCW.

Critique of the Incineration Alternative

1. It has already been tested and proved feasible and relatively efficient.
2. It breaks down the toxic solvents to CO_2 and H_2O .
3. It is a costly process which requires a special facility to run its operation.
4. If the waste must be shipped to a central incinerator site, costs and hazards of transportation are involved.
5. Incineration results in the release of radioactive materials to the environment. Environmental impacts must be carefully evaluated on a case by case basis.

2. Addition to Fuel

The five methods discussed previously for the disposal of LSC organic solvents completely ignore the energetic value of some of these solvents. The University of Illinois¹⁰ has incorporated the LSCW (without phase separations) into their heating oil. The combustion of toluene and xylene can produce a considerable amount of thermal energy. Burning such solvents as a heat source is a better use of our resources than incinerating, burying or disposal as trash. However, it is perhaps not the best utilization of their contained energy, because it is like burning gasoline as a source of heat. Toluene and xylene are prime constituents of gasoline. They have high octane numbers, thus they are very desirable for engine combustion^{9*} because of this antiknock quality (see Table V). The toluene and xylene wastes could, after separation from the

*Some of the information was obtained by telephone conversation between L. Roche-Farmer and technical staff of Arco Chemical Division of Atlantic Richfield Petroleum Corporation.

aqueous phase, be added to gasoline and thus disposed of in a useful manner. The aqueous phase could be disposed of in the sewer under 10 CFR 20 provisions. The organic solvents would have some residual aqueous (tritiated) material after phase separation, but it would be a very small fraction of what already had very small radiation content. A rough estimate of the dilution factor involved was calculated. Normal hexane was taken as a model for engine combustion. Approximately 1 liter of fuel would produce 8,000 liters of gases at the exhaust, or a dilution factor of 1:8000.

Critique of Addition of Organic Solvents to Fuel

1. Produces energy.
2. Result is the release of some radioactivity to the environment which must be evaluated.
3. 10 CFR Part 20 would probably allow addition of organic solvents to heating oil under the incineration provisions for a specific licensee.
4. Addition to gasoline would require an amendment to the regulations.
5. If added to gasoline, an aqueous phase separation would likely be needed.
6. These are probably the simplest methods for disposal of LSCW.

IV. Summary

Evaporation is not a safe or efficient method to dispose of the LSCW. Distillation does not seem to be practical nor economically feasible for the small laboratory. However, industry has used the process successfully on a routine basis. If the supply of toluene and xylene becomes scarce due to competition from gasoline and other chemical users, it might be worthwhile to recover these solvents by distillation processes.

Solidification methods need further development. They also require expense and effort of specialized personnel. If successful methods are found, it should provide a safer LSCW form for transportation and disposal by burial in the ground. However, solids would be expected to break down in the ground over the long term.

Conversion of toluene and xylene to less hazardous chemical forms by a simple oxidation procedure seems to have some potential. Chemical conversion must be tested in the laboratory but it is relatively simple and inexpensive which might make it suitable for a small research laboratory. In general, it would probably be more acceptable to the environmentalists than the combustion techniques (incineration and addition to gasoline or heating oil).

Incineration is a technique which has already been tested for LSCW at the Mound Facility. Ideally it should break down the toxic solvents to CO_2 and H_2O , but it is obvious that some of the LSCW generators cannot afford the cost of this technique. For those who cannot, who are the majority, it would mean having to transport the waste to the incineration facility. Thus, transportation hazards and cost are the primary major disadvantages of this alternative.

Combustion of toluene and xylene, which are the solvents mostly used in the cocktails as a source of energy, seems the simplest and most useful disposal alternatives. Addition of the organic solvents to the heating oil would probably be allowed under the regulations on a case by case basis. But addition to gasoline would require an amendment to the regulations.

Reduction of the volume of waste generated at the source would likely simplify its disposal. Segregation of the waste by radioactivity concentration and by solvent has been found helpful in managing the waste by manufacturers of radioactive chemicals.⁷ The staff of the commercial burial grounds has surveyed shipments of radioactive-labelled waste which proved to be non-radioactive. Thus, better control of the LSCW at the source by encouraging reduction of volume and radioactivity segregation might be helpful procedures in the management of the waste.

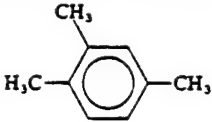

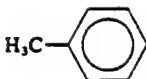

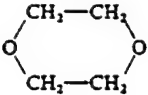

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7. Information obtained by staff visit to New England Nuclear, Boston, Massachusetts, in August 9 and 10, 1979.
8. Information obtained by staff visit to the Mound Facility, Monsanto Research Corporation, Miamisburg, Ohio, in September 20, 1979.
9. Chemical and Engineering News, Issue of December 11, 1978, page 12, "Gasoline, Chemicals Producers Vie for Toluene," and page 13, "Pressures on O-Xylene Use Raise Price Tag."
10. Information obtained from NRC Material Licensing Files, University of Illinois, Urbana, Illinois, June 4, 1976.

Table I

Relative Scintillation Yields
of Some Commonly Used Solvents

Solvent	Structure	Relative scintillation yield ^a
1,2,4-Trimethylbenzene		112
<i>p</i> -Xylene		110
Toluene		100
Benzene		85
Dioxane		65
Cyclohexane		70

^aMeasured by relative (toluene = 100) pulse height of the Compton edge for the 662-keV γ rays of ^{137}Ba .

Donald L. Horrocks, "Applications of Liquid Scintillation Counting," Table III-1, page 38, Academic Press (1974). Permission to use this copyrighted material was granted by Academic Press.

Table II

Toxicity of Toluene, Xylenes
and 1,2,4-trimethylbenzene (Pseudocumene)

TOLUENE ***General Information**

Synonyms: methylbenzene; phenylmethane; toluol.

Colorless liquid; benzol-like odor.

Formula: $C_6H_5CH_3$.

Mol wt: 92.13, mp: $-95^{\circ}C$ to $-94.5^{\circ}C$, bp: $110.4^{\circ}C$,

flash p.: $40^{\circ}F$ (C.C.), ulc: 75-80, lel = 1.27%, uel

7.0%, d: 0.866 at $20^{\circ}/4^{\circ}C$, autoign. temp.: $947^{\circ}F$,

vap. press.: 36.7 mm at $30^{\circ}C$, vap. d.: 3.14.

Hazard Analysis**Toxic Hazard Rating:**

Acute Local: Irritant 1.

- Acute Systemic: Ingestion 2; Inhalation 2; Skin Absorption 1.

Chronic Local: Irritant 1.

Chronic Systemic: Ingestion 2; Inhalation 2; Skin Absorption 2.

Toxicology: Toluene is derived from coal tar, and commercial grades usually contain small amounts of benzene as an impurity. Acute poisoning, resulting from exposures to high concentrations of the vapors, are rare with toluene. Inhalation of 200 ppm of toluene for 8 hours may cause impairment of coordination and reaction time; with higher concentrations (up to 800 ppm) these effects are increased and are observed in a shorter time. In the few cases of acute toluene poisoning reported, the effect has been that of a narcotic, the workman passing through a stage of intoxication into one of coma. Recovery following removal from exposure has been the rule. An occasional report of chronic poisoning describes an anemia and leucopenia, with biopsy showing a bone marrow hypoplasia. These effects, however, are less common in people working with toluene, and they are not as severe.

* This material has been assigned a Threshold Limit Value by ACGIH. See complete reprint of TLV's in Section 1.

Exposure to concentrations up to 200 ppm produces few symptoms. At 200 to 500 ppm, headache, nausea, loss of appetite, a bad taste, lassitude, impairment of coordination and reaction time are reported, but are not usually accompanied by any laboratory or physical findings of significance. With higher concentrations, the above complaints are increased and in addition, anemia, leucopenia and enlarged liver may be found in rare cases.

A common air contaminant.

Fire Hazard: Dangerous, when exposed to heat or flame.

Spontaneous Heating: No.

Explosion Hazard: Moderate, when exposed to flame.

Disaster Hazard: Moderately dangerous; when heated, it emits toxic fumes; can react vigorously with oxidizing materials.

Countermeasures

Ventilation Control: Section 2.

To Fight Fire: Foam, carbon dioxide, dry chemical or carbon tetrachloride (Section 7).

Personnel Protection: Section 2.

Storage and Handling: Section 7.

Shipping Regulations: Section 11.

Regulated by IATA.

From DANGEROUS PROPERTIES OF INDUSTRIAL MATERIALS, 5th edition by N. Irving Sax (c) 1975 by Litton Educational Publng. Reprinted by permission of Van Nostrand Reinhold Company.

Table II (cont'd)

m-XYLENE ***General Information**Synonym: *m*-xylol.

Colorless liquid.

Formula: $C_8H_{10}(CH_3)_2$.Mol wt: 106.2, mp: -47.9°C, bp: 139°C, lel = 1.1%,
uel = 7.0%, flash p.: 84°F, d: 0.864 at 20°/4°C,
vap. press.: 10 mm at 28.3°C, vap. d.: 3.66, autoign.
temp.: 982°F.**Hazard Analysis****Toxic Hazard Rating:**

Acute Local: Irritant 1.

Acute Systemic: Inhalation 2; Skin Absorption 2.

Chronic Local: Irritant 1.

Chronic Systemic: Inhalation 2; Skin Absorption 2.

Note: A common air contaminant. Oral MLD (rats) =
4 g/kg.Fire Hazard: Dangerous, when exposed to heat or
flame; can react with oxidizing materials.Explosion Hazard: Moderate, in the form of vapor
when exposed to heat or flame.Disaster Hazard: Dangerous. Keep away from open
flame.**Countermeasures**

Ventilation Control: Section 2.

To Fight Fire: Foam, carbon dioxide, dry chemical or
carbon tetrachloride (Section 7).

Personnel Protection: Section 2.

Storage and Handling: Section 7.

Shipping Regulations: Section 11.

Regulated by CG, DOT, IATA.

o-XYLENE ***General Information**Synonym: *o*-xylol.

Colorless liquid.

Formula: $C_8H_{10}(CH_3)_2$.Mol wt: 106.2, bp: 144.4°C, fp: -25.5°C, ulc: 40-45,
lel = 1.0%, uel = 6.0%, flash p.: 115°F (T.O.C.),
d: 0.880 at 20°/4°C, vap. press.: 10 mm at 32.1°C,
vap. d.: 3.66, autoign. temp.: 867°F.**Hazard Analysis**Toxicity: See *m*-xylene.

Note: A common air contaminant.

Fire Hazard: Moderate, when exposed to heat or flame;
can react with oxidizing materials.Explosion Hazard: Slight, in the form of vapor when
exposed to heat or flame.**Countermeasures**

Ventilation Control: Section 2.

To Fight Fire: Foam, carbon dioxide, dry chemical or
carbon tetrachloride (Section 7).

Storage and Handling: Section 7.

Shipping Regulations: Section 11.

Regulated by CG, DOT, IATA.

p-XYLENE ***General Information**Synonym: *p*-xylol.

Clear liquid.

Formula: $C_8H_{10}(CH_3)_2$.Mol wt: 106.2, bp: 138.3°C, lel = 1.1%, uel 7.0%, fp:
13.2°C, flash p.: 103°F (T.O.C.), d: 0.8611 at
20°/4°C, vap. press.: 10 mm at 27.3°C, vap. d.:
3.66.**Hazard Analysis**Toxicity: See *m*-xylene.

Note: A common air contaminant.

Fire Hazard: Moderate, when exposed to heat or flame;
can react with oxidizing materials.Explosion Hazard: Moderate in the form of vapor when
exposed to heat or flame.**Countermeasures**

Ventilation Control: Section 2.

To Fight Fire: Foam, carbon dioxide, dry chemical or
carbon tetrachloride (Section 7).

Storage and Handling: Section 7.

Shipping Regulations: Section 11.

Regulated by CG, DOT, IATA.

Table II (cont'd)

PSEUDOCUMENE**General Information**

Synonyms: 1,2,4-trimethylbenzene; pseudocumol.
Liquid; insol. in water; sol. in alcohol, benzene, and ether.

Formula: $(C_6H_5)(CH_3)_3$.
Mol wt: 120.19, d: 0.888(4°/4°C), fp: -61°C, bp: -168.89°C, flash p.: 130°F.

Hazard Analysis**Toxic Hazard Rating:**

Acute Local: Irritant 1.
Acute Systemic: Inhalation 2; Ingestion 2; Skin Absorption 2.

Chronic Local: U.
Chronic Systemic: Inhalation 2; Skin Absorption 2.
Toxicology: Can cause CNS depression, anemia, bronchitis. I.p. LD (rats) = 2 g/kg.

Fire Hazard: Moderate, where exposed to heat or flame.
Countermeasures

Storage and Handling: Section 7.

To Fight Fire: Foam, alcohol foam, mist (Section 7).

1,4-DIOXANE ***General Information**

Synonyms: p-dioxane; diethylene oxide; diethylene dioxide.

Colorless liquid, pleasant odor.

Formula: $OCH_2CH_2OCH_2CH_2$.

Mol wt: 88.10, mp: 12°C, bp: 101.1°C, lei = 2.0%, uel = 22.2%, flash p.: 54°F (C.C.), d: 1.0353 at 20°/4°C, autoign. temp.: 356°F, vap. press.: 40 mm at 25.2°C, vap. d.: 3.03.

Hazard Analysis**Toxic Hazard Rating:**

Acute Local: Irritant 2.
Acute Systemic: Ingestion 3; Inhalation 3; Skin Absorption 2.

Chronic Local: U.

Chronic Systemic: Ingestion 3; Inhalation 3; Skin Absorption 2.

This material is an experimental carcinogen (Section 8).
Toxicology: Exposure of animals to concentration of 0.1 to 3% of dioxane vapor causes irritation of the eyes and nose, followed by narcosis and/or pulmonary edema and death. The irritative effects probably provide sufficient warning, in acute exposures, to enable the workman to leave exposure before he is seriously affected. On the other hand, repeated exposure to low concentrations has resulted in human fatalities, the organs chiefly affected being the liver and kidneys. Death resulted from acute hemorrhagic nephritis. The hepatic lesion consists of an acute central necrosis of the lobules. The brain and lungs may show acute edema.

In acute exposures, the signs and symptoms consist of irritation of the eyes and naso-pharynx, which may later subside, to be followed by headache, drowsiness, dizziness, and occasionally nausea and vomiting. In chronic exposures, there may be loss of appetite, nausea and vomiting, pain and tenderness in the abdomen and lumbar region, malaise, and enlargement of the liver without jaundice. There may be changes in the blood picture. Further exposure may result in suppression of urine, followed by uremia and death.

Fire Hazard: Dangerous, when exposed to heat or flame; can react vigorously with oxidizing materials.

Explosion Hazard: Moderate, when exposed to flame or by chemical reaction with oxidizers.

Countermeasures

Ventilation Control: Section 2.

To Fight Fire: Alcohol foam, carbon dioxide, dry chemical or carbon tetrachloride (Section 7).

Personnel Protection: Section 2.

Storage and Handling: Section 7.

Shipping Regulations: Section 11.

Regulated by IATA.

Table III
Physical Properties of Solvents Used in Most Common LSC Cocktails*

<u>Product</u>	<u>Base Solvent</u>	<u>Flash Point (T.C.C.)¹</u>	<u>Boiling Point of Pure Solvent</u>	<u>Vapor Pressure (at 25°C)⁴</u>	<u>Manufacturer</u>	<u>TLV⁵</u>
<u>Organic Counting</u> <u>(Non-Aqueous)</u>						
4a20	Xylene	80°F	o - 291.2°F ² m - 282.2°F p - 280.4°F	9 mmHg	Research Products International	100ppm
Betafluor	Aromatic	(151) ⁶ F		2 mmHg	National Diagnostics	*
Econofluor	Xylene	72°F		9 mmHg	New England Nuclear	100ppm
Liquifluor	Toluene	40°F	231.1°F	27.5 mmHg	New England Nuclear	100ppm
LSC	Toluene	41°F		27.5 mmHg	Yorktown	100ppm
OCS	Xylene	79°F		9 mmHg	Amersham	100ppm
<u>Aqueous Counting</u>						
ACS	Xylene	58°F		9 mmHg	Amersham	100ppm
Aquasol	Xylene	97°F		9 mmHg	New England Nuclear	100ppm
Aquasure	Pseudocumene	(121°)F	337.1°F	2 mmHg	New England Nuclear	25ppm
Biofluor	Pseudocumene	122°F		2 mmHg	New England Nuclear	25ppm
Filtron - X	Dioxane	54°F	213.8°F ³	40 mmHg	National Diagnostics	50ppm
GP	Toluene	(47°)F		27.5 mmHg	Beckman	100ppm
HP	Toluene	(44°)F		27.5 mmHg	Beckman	100ppm
Hydrofluor	Aromatic	(148°)F		2 mmHg	National Diagnostics	*
Hydromix	Xylene	68°F		9 mmHg	Yorktown	100ppm
Insta-Gel	Xylene	84°F		9 mmHg	Packard	100ppm
Monofluor	Aromatic	(149°)F		2 mmHg	National Diagnostics	*
Riafluor	Pseudocumene	126°F		2 mmHg	New England Nuclear	25ppm
Ultrafluor	Aromatic	(149°)F		2 mmHg	National Diagnostics	*

Table III (cont'd)

* Table III was obtained from NIH Safety Office and may not represent a complete list of all the products on the market. Flash point determinations were made by the NIH Quality Assurance Branch.

- 1 Flash point is the minimum temperature of a liquid at which sufficient vapor is given off to form an ignitable mixture with the air near the surface of the liquid.
A liquid having a flash point of 50°F is much more flammable than a liquid having a flash point of 140°F.
- 2 There are three xylene isomers, i.e., ortho, meta and para.
- 3 There are two isomers for dioxane, i.e., 1,3 and 1,4 dioxane.
The boiling point given in the table is for 1,4 dioxane.
- 4 Vapor pressure is the pressure characteristic at any given temperature of a vapor in equilibrium with its liquid or solid form. Both vapor pressure and TLV data should be examined when determining overall toxicity since a low vapor pressure would indicate less chance for exposure.
- 5 Threshold Limit Value is the average concentration for a normal 8-hour workday to which nearly all workers may be repeatedly exposed, day after day, without adverse effect.

Table IV

Toxicity of Benzoic Acid and Phthalic Acid

BENZOIC ACID**General Information**

Synonym: phenylformic acid.

White powder.

Formula: C_6H_5COOH .

Mol wt: 122.12, mp: 121.7°C, bp: 249°C, flash p.: 250°F (C.C.), d: 1.316, autoign. temp.: 1065°F, vap. press.: 1 mm at 96.6°C (sublimes), vap. d.: 4.21.

Hazard Analysis**Toxic Hazard Rating:**

Acute Local: Irritant 1; Ingestion 1; Inhalation 1.

Acute Systemic: Ingestion 1.

Chronic Local: 0.

Chronic Systemic: Ingestion 1.

A chemical preservative food additive (Section 10).

Fire Hazard: Slight, when exposed to heat or flame; can react with oxidizing materials.

Spontaneous Heating: No.

Countermeasures

To Fight Fire: Water, carbon dioxide, water spray or mist, dry chemical or carbon tetrachloride (Section 7).

Ventilation Control: Section 2.

Personal Hygiene: Section 2.

Storage and Handling: Section 7.

PHTHALIC ACID**General Information**

Synonym: benzene dicarboxylic acid.

Crystals.

Formula: $C_6H_4O_4$.

Mol wt: 166.1, mp: 206–208°C, d: 1.59.

Hazard Analysis**Toxic Hazard Rating:**

Acute Local: Allergen 1; Irritant 2.

Acute Systemic: U.

Chronic Local: Allergen 1.

Chronic Systemic: U.

Oral LD₅₀ (rats) = 8 g/kg.

Fire Hazard: Slight, when heated (Section 7).

Countermeasures

Personal Hygiene: Section 2.

Storage and Handling: Section 7.

Table V

Research Octane Ratings of Hydrocarbons

Name	Formula	Octane number
ALKANES		
C ₄ <i>n</i> -Butane	CH ₃ CH ₂ CH ₂ CH ₃	94
Isobutane	CH ₃ CH(CH ₃) ₂	101
C ₅ <i>n</i> -Pentane	CH ₃ (CH ₂) ₃ CH ₃	62
2-Methylbutane	CH ₃ CH ₂ CH(CH ₃) ₂	92
C ₆ <i>n</i> -Hexane	CH ₃ (CH ₂) ₄ CH ₃	25
2-Methylpentane	CH ₃ (CH ₂) ₂ CH(CH ₃) ₂	73
3-Methylpentane	CH ₃ CH ₂ CH(CH ₃)CH ₂ CH ₃	75
2,2-Dimethylbutane (neohexane)	CH ₃ CH ₂ C(CH ₃) ₃	92
2,3-Dimethylbutane	CH ₃ CH(CH ₃)CH(CH ₃)CH ₃	102
C ₇ <i>n</i> -Heptane	CH ₃ (CH ₂) ₅ CH ₃	0
C ₈ 3-Methylheptane	CH ₃ (CH ₂) ₃ CH(CH ₃)CH ₂ CH ₃	27
3-Ethylhexane	CH ₃ (CH ₂) ₂ CH(C ₂ H ₅)CH ₂ CH ₃	34
2,2-Dimethylhexane	CH ₃ (CH ₂) ₃ C(CH ₃) ₃	73
2-Methyl-3-ethylpentane	CH ₃ CH ₂ CH(C ₂ H ₅)CH(CH ₃) ₂	87
2,2,4-Trimethylpentane (isooctane)	(CH ₃) ₃ CCH ₂ CH(CH ₃) ₂	100
ALKENES		
Butene-1	CH ₃ CH ₂ CH=CH ₂	97
Butene-2	CH ₃ CH=CHCH ₃	100
Pentene-1	CH ₃ CH ₂ CH ₂ CH=CH ₂	91
2-Methylbutene-2	CH ₃ C(CH ₃)=CHCH ₃	97
Hexene-2	CH ₃ (CH ₂) ₂ CH=CHCH ₃	93
NAPHTHENES		
Methylcyclopentane	C ₅ H ₉ CH ₃	91
Ethylcyclopentane	C ₅ H ₉ CH ₂ CH ₃	67
Cyclohexane	C ₆ H ₁₂	83
Methylcyclohexane	C ₆ H ₁₁ CH ₃	75
AROMATICS		
Toluene	C ₆ H ₅ CH ₃	107
Ethylbenzene	C ₆ H ₅ CH ₂ CH ₃	104
<i>n</i> -Propylbenzene	C ₆ H ₅ CH ₂ CH ₃	105

APPENDIX 1
GUIDELINE FOR
INCINERATION OF LIQUID SCINTILLATION WASTE

1. Specify the nuclides which will be contained in the liquid scintillation waste.
2. Specify the approximate concentration of each nuclide and total quantity of radioactivity in material which will be incinerated in a single burn. Estimate the quantity of radioactivity in material to be incinerated per year.
3. Provide information concerning the characteristics of the incinerator including temperature, air flow, and stack height.
4. Provide information concerning the location of the incinerator with respect to occupied buildings and areas in the vicinity. A sketch showing distances to occupied areas and buildings, prevailing wind direction, and designation of north should be provided.
5. Provide information concerning anticipated concentrations of nuclides at the exit of the incinerator stack. If concentrations will not exceed 10% of those specified in Appendix B, Table II, Column 1, 10 CFR Part 20, no further information concerning concentrations is necessary. If higher concentrations are anticipated, provide calculations which demonstrate

that individuals in the unrestricted area are not likely to be exposed to concentrations of radioactivity in excess of 10% of those specified in Appendix B, Table II, Column 1, of 10 CFR Part 20.

6. If nuclides contained in the liquid scintillation waste will not be volatilized, provide procedures for collection, handling, and disposal of residues in the incinerator including radiation safety precautions for performing these operations.
7. Provide evidence of compliance with all State and local regulations concerning incinerations of radioactive material.

APPENDIX 2

RADIATION DOSE ASSESSMENT

The following calculations have been performed to assess the dose to a maximally exposed individual from incinerator effluents produced in the disposal of liquid scintillation counting waste by combustion. As shown below, the assumptions for the calculations are extremely conservative yielding results higher than would be expected from an actual facility. The effluent concentrations and subsequent dose commitments are normalized to one Ci per year for tritium and 0.01 Ci per year for ^{14}C . Once exiting the incinerator, the activity is diluted by an atmospheric dilution factor of 10^{-3} sec/m^3 .^{*} The facility is assumed to be in operation for 2000 hours per year. The concentration of radioactive effluents at the location of interest is calculated as follows:

$$\frac{1 \text{ Ci}}{2000 \text{ hours}} \times 10^{-3} \frac{\text{sec}}{\text{m}^3} \times \frac{\text{hour}}{3600 \text{ sec}} = 1.39 \times 10^{-10} \frac{\text{Ci}}{\text{m}^3}$$

A teenager is assumed to receive the potential maximum dose from inhaling tritium and a child from inhaling ^{14}C . Regulatory Guide 1.109 is used as the basis for breathing rate calculations as well as for both inhalation dose conversion factors used in this analysis.

$$8000 \frac{\text{m}^3}{\text{yr}} \times \frac{\text{yr}}{8766 \text{ hr}} \times 2000 \frac{\text{hr}}{\text{yr}} = 1.83 \times 10^3 \frac{\text{m}^3}{\text{yr}} ; \text{ teenager/adult}$$

$$3700 \frac{\text{m}^3}{\text{yr}} \times \frac{\text{yr}}{8766 \text{ hr}} \times 2000 \frac{\text{hr}}{\text{yr}} = 8.44 \times 10^2 \frac{\text{m}^3}{\text{yr}} ; \text{ child}$$

^{*}For dose calculational purposes in an unknown environment, we have assumed that a dilution factor (X/Q) of 10^{-3} sec/m^3 is an appropriate upper bound at short (10-40 m) distances.

Using the dose conversion factor of $1.59 \times 10^{-7} \frac{\text{mrem}}{\text{pCi}}$ from the Regulatory Guide we calculate:

$$139.0 \frac{\text{pCi}}{\text{m}^3} \times 1.83 \times 10^3 \frac{\text{m}^3}{\text{yr}} \times 1.59 \times 10^{-7} \frac{\text{mrem}}{\text{pCi}} = 4.04 \times 10^{-2} \frac{\text{mrem}}{\text{yr}}$$

For ^{14}C , the maximum affected organ from inhalation is the bone. Substituting the dose conversion factor from the Regulatory Guide and assuming a release of 10 millicuries, the bone dose to a child can be calculated.

$$1.39 \frac{\text{pCi}}{\text{m}^3} \times 8.44 \times 10^2 \frac{\text{m}^3}{\text{yr}} \times 9.70 \times 10^{-6} \frac{\text{mrem}}{\text{pCi}} = 1.14 \times 10^{-2} \frac{\text{mrem}}{\text{yr}}$$

Ingestion Pathway:

For each calculation, the dose calculational methods and associated conversion factors are those developed by Oak Ridge National Laboratories and presented in ORNL-4992, A Methodology for Calculating Radiation Doses from Radioactivity Released to the Environment.

Assuming food and drinking water to be in equilibrium with the specific activity of ^3H in the atmosphere, the corresponding dose rate factors for ^3H are $3.65 \times 10^9 \frac{\text{mrem}/\text{Ci}}{\text{yr}/\text{m}^3}$ and $3.37 \times 10^9 \frac{\text{mrem}/\text{Ci}}{\text{yr}/\text{m}^3}$, respectively.

When the source and amount of drinking water is not defined, it is assumed that the atmospheric ^3H is diluted by a factor of 10^2 producing a dose factor of $3.37 \times 10^7 \frac{\text{mrem}/\text{Ci}}{\text{yr}/\text{m}^3}$ for that pathway. The dose rate then, for ^3H ingested in both food and drinking water is conservatively $3.68 \times 10^9 \frac{\text{mrem}/\text{Ci}}{\text{yr}/\text{m}^3}$.

From before,

$$3.68 \times 10^9 \frac{\text{mrem}}{\text{yr}} \frac{\text{m}^3}{\text{Ci}} \times 1.39 \times 10^{-10} \frac{\text{Ci}}{\text{m}^3} = 5.12 \times 10^{-1} \frac{\text{mrem}}{\text{yr}}$$

To calculate the dose from ingestion of ^{14}C , it is assumed that the specific activity in human tissue is equal to the average steady state value in the atmosphere. Based on this assumption, a dose factor of $2.22 \times 10^{12} \frac{\text{mrem}}{\text{yr}} \frac{\text{Ci}}{\text{m}^3}$ was used. As stated before, this dose factor was taken from ORNL-4992 with the red marrow as critical organ.

Using this dose factor as well as the concentration calculated before, we get

$$2.22 \times 10^{12} \frac{\text{mrem}}{\text{yr}} \frac{\text{m}^3}{\text{Ci}} \times 1.39 \times 10^{-12} \frac{\text{Ci}}{\text{m}^3} = 3.09 \frac{\text{mrem}}{\text{yr}}$$

Appendix 1 and Appendix 2 prepared by staff of the Division of Fuel Cycle and Material Safety, Office of Nuclear Material Safety and Safeguards.

NRC FORM 335 (7-77)		U.S. NUCLEAR REGULATORY COMMISSION BIBLIOGRAPHIC DATA SHEET		1. REPORT NUMBER (Assigned by DDC) NUREG-0656	
4. TITLE AND SUBTITLE (Add Volume No., if appropriate) Study of Alternative Methods for the Management of Liquid Scintillation Counting Wastes				2. (Leave blank)	
7. AUTHOR(S) Lidia Roche-Farmer, Ph.D.				3. RECIPIENT'S ACCESSION NO.	
9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) U.S. Nuclear Regulatory Commission Division of Fuel Cycle and Material Safety Office of Nuclear Material Safety and Safeguards Washington, D.C. 20555				5. DATE REPORT COMPLETED MONTH January YEAR 1980	
12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code) U.S. Nuclear Regulatory Commission Division of Fuel Cycle and Material Safety Office of Nuclear Material Safety and Safeguards Washington, D.C. 20555				DATE REPORT ISSUED MONTH February YEAR 1980	
13. TYPE OF REPORT Technical Report				6. (Leave blank)	
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16. ABSTRACT (200 words or less) The Nuclear Engineering Waste Disposal Site in Richland, Washington, is the only radioactive waste disposal facility that will accept liquid scintillation counting wastes (LSCW) for disposal. That site is scheduled to discontinue receiving LSCW by December of 1982. The objective of this document is to study alternative methods for the management of LSCW which constitutes 40% in volume of the institutional waste generated in the U.S. The LSCW total radioactivity content is estimated at 8 Ci/year. Although this amount of radioactivity is relatively small, LSCW must be treated as radioactive waste under existing regulations. Disposal problems are compounded and some options limited because of the chemical nature of the organic solvents, e.g., their flammability and chemical toxicity. The techniques that have been evaluated as alternative methods for the management of LSCW are: (1) evaporation, (2) distillation, (3) solidification, (4) conversion to a less hazardous chemical form, and (5) combustion (which includes incineration and addition to fuel). Presently, incineration appears to be the most viable alternative although some of the other methods seem promising but require further development. Also, the waste disposal is likely to be simplified by reduction of the volume generated at the source and segregation of the waste by radioactivity concentration.				11. CONTRACT NO.	
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